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HYDRO- MORPHOLOGICAL STUDY FOR REHABILITATION OF OLD MADHUMATI RIVER USING MATHEMATICAL MODEL

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ABSTRACT

Restoration of any river is indispensable to conserve and restore the surrounding environment. River restoration through dredging is one of the primary solutions for rehabilitation of rivers those get silted up causing adverse impacts on the state of the river channel and its morphology. Restoration of old channel now dead but once a flowing channel is a very complex tasks and need cautious attention regarding selection of its alignment, re-excavation volume and sustainability of dredge channel. Uses of modeling tools are very crucial for understanding the scenarios on future performance after rehabilitation and its sustainability. An in-depth study has been performed to restore the Old Madhumati River, which is situated in the southwest region of Bangladesh. Once it was a free flowing river now became silted up causing serious environmental degradation in the surrounding area. Under this obstinately changing morphological condition of Old Madhumati river, the study included review, collection of time series satellite images, scenario development for cross-sections, velocity, setting the alignment of dredging, estimates of dredging using mathematical modeling which will authenticate sustainability. Careful investigation was conducted to examine whether the dredged canal needs supplementary measure to keep it hydraulically alive throughout the year or not including preliminary study on the environmental impacts.

Keywords: *Rehabilitation, River morphology, Dredging, Mathematical modeling, Sustainability*

1. INTRODUCTION

Bangladesh is a land of rivers and the environment and the life and livelihood of millions of people of Bangladesh are dependanr on riverine emvironment. Environment is the aggregate of conditions affecting the existence or development of life and nature. The overall global environment has undergone degradation due to the various development efforts and in Bangladesh it is declining faster for many obvious reasons, the main being due to the population pressure. Many silted up rivers have been occupied by the growing population and/or increasing food production as a result of population increase. Re-excavation of silted up rivers and channels bring immense benefit to maintain land and water equilibrium of an area provided that the re-excavated earth is disposed properly. It also brings various socio- economic benefits to the local people, although it involves quite a lot of finances. Proper re-excavation of rivers and channels also contributes to environmental development and restoration of an area.

Reduction of fresh water flow, over the years, through the Gorai has imparted significant impact on the river system of the southwest region of Bangladesh. Prior to implementation of the Farakka barrage, south west region of Bangladesh did not face acute shortage of flow since the flow of the Gorai and other tributaries of the Ganges towards this region were sufficient to meet up the requirement for maintenance of environment and sustenance of livelihood of the people of the region. Another important river, which also contributes to fresh water to this region, is the Arial khan from which Kumar, Madaripur Beel Route (MBR) and other important tributaries take off. In the recent past, on account of declining flow of the Ganges, Gorai offtake has been silted up and flow through this river towards the southwest region started to face shortage of flow, especially during dry season when no flow condition exists. On the contrary, flow of the Arial Khan did not show any indication of declining tendency, but flow of the Kumar reveals receipt of less amount of flow (SWMC 2002). It is known that within the basin of the Arial Khan-Kumar, some irrigation projects have been implemented during last few decades. Due to shortage of flow, overall hydro-morphological situation in the rivers of this region has been degraded. During dry period, tidal flow dominates and the sediment, which comes along with the tide, deposits. No significant flow comes from upstream to push the sediment load towards the sea that ultimately piles up degrading overall morphological condition at the downstream. Such relentless degradation might cause total closure of the flow through a branch of the Madhumati River entering into the Gopalganj town by isolating the Chapail area that meets the Madaripur Beel Route canal. Few years back, this linking branch channel was free-

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flowing River which gradually srank to a seasonally flowing river and is now locally named as Old (Mora) Madhumati River. The channel is now a leftover and saturated with water hyacinths during monsoon. Other than monsoon, it remains dry for most of the time. Every year during monsoon, both banks of the channel gets inundated due to siltation on the channel bed. Water of the river Mora Modhumati becomes polluted mainly due to disposal of sewerage wastes and other city wastes, which become severe during the dry period. Boat communication in the Mora Modhumati River has been limited due to siltation. Water quantum, flow and tidal prism have been reduced due to siltation mainly and they affected the growth of aquatic flora and fauna both qualitatively and quantitatively. At present people of the areas, specially living beside the river suffer from availability of surface water seasonally, mainly used for bathing, bathing of livestock and domestic purposes. Fish production and availability has also been reduced due to drying and pollution of habitat (IWM 2006).

2. STUDY OBJECTIVES

In view of the above background information, rehabilitation of Old Madhumati River through re-excavation has become a necessity to meet the public demands. Investigation intended to cover the hydro-morphological condition of the Madhumati canal integrating the Madhumati-Madaripur Beel Route (MBR) river system in order to determine the suitability of re-excavation, verify the suitability of existing alignment, sequence of re-excavation and required re-excavation volume to maintain the stable hydraulic regime section for continuous flow round the year. Investigations of these hydraulic issues have been carried out with the application of mathematical models. The core of the mathematical modeling study is the application of the MIKE21C modeling system, which is an advanced two-dimensional mathematical modeling. The tool helps assessing the various options on selection of dredging alignment, dredging quantity, depth, width, possible velocity and quantum of flow through the dredged channel etc which helps determining the sustainability of the rehabilitation works of the Old (Mora) Modhumati River.

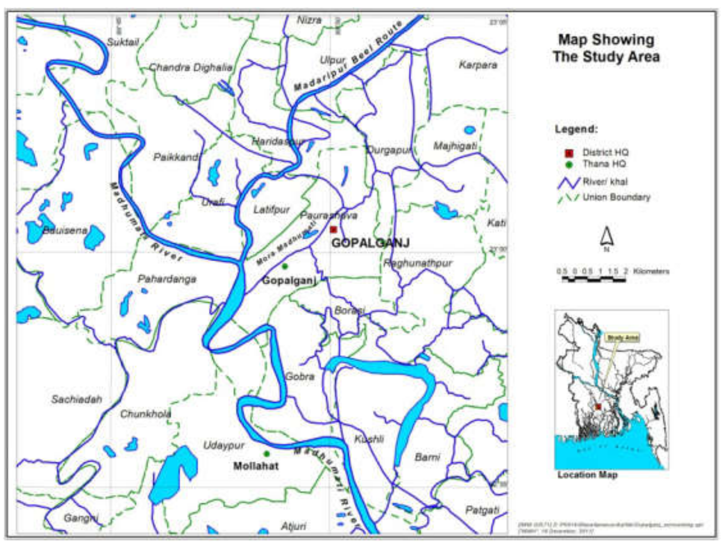

Figure 1 Map Showing the study area and adjoining river system

3. REVIEW

Gorai flow has been interrupted and redueced during lean season, causing a lot of harm and degradation of the environmental and socio economic conditions along the river due to implementation of diversion of lean flow water at the Barrage in Farakka since 1975 (Hossain 1989). In the Southwest Area Water Resources Management Project (FAP4, 1993) executed in the period of 1991 to 1993, different scenarios for augmentation of the dry season flow in the Gorai river were investigated by one dimensional model. One of the schemes was dredging of a deep channel along the thalweg of the upper 30 kilometers of the Gorai river. Guide banks and groynes were suggested for the scheme. A two dimensional pilot model of the Gorai offtake including part of the Ganges was developed by the River Survey Project (FAP24 1996) using a large set of coherent data collected during 1995 and 1996 under FAP24 project. Following the signature of the Ganges water Sharing Treaty, studies were initiated under the Task Force by BWDB to steer the implementation of a scheme to restore the flow in the Gorai, based on the options identified by the Southwest Area Water Resources Management Project. As a follow up of this the Government has implemented GRRP phase I and also Phase II and currently the Ganges Barrage study is going on with a view to augmenting the Gorai River flow and to restore the ecosystem of the Southwest Bangladesh. Hossain et al (2003) and Hossain and Zaman (1996) studied the sediment transport and morphological aspects of the river system of the region including Gorai and Arial khan river which givers a very clear overview on the water management of the area. In addition to reviews mentioned above, studies on hydraulic process behind the siltation at the mouth of the old Madhumati canal from different literature, study, reports and paper from internet have been consulted (Hosain1992a, 1992b; Edmund and Slingerland 2007). The study area including the adjoining river system is shown if Fig. 1.

4. DATA AND METHODOLOGY

Various kinds of hydrometric data of recent and previous years have been collected and compiled. Main source of these data is IWM survey/measurement carried out during 2009 and 2010. Other sources are BWDB and CEGIS. During 2009 and 2010, water level and velocity data have been collected by survey group of IWM. As a part of updating the south west region model (SWRM) of Bangladesh to support flood forecasting and warning centre, BWDB, IWM routinely collects bathymetric data of the major rivers of this region. During December 2009 and June 2010 bank line data has been surveyed by IWM. Sediment data during June 2010 were collected at two locations; at Chapail ghat near the downstream end of the old Madhumati canal and the other at Haridashpur Bridge by IWM. Planform characteristics of the Old Madhumati and MBR-Madhumati confluence have been analyzed with the help of available satellite imagery of 2001, 2003 and 2005 collected from CEGIS.

Prior to development of the mathematical modeling, data analysis have been done extensively from the basis of hydraulic process of the Madhumati and MBR river system. The analysis of the data focused on the present and past morphological condition at the vicinity of the old Madhumati canal the sediment process, evolution of the channel and changes in the channel geometry etc. The study has also assessed the necessity of suitable type of structural interventions in order to keep the river in flowing stage. To achieve this, collection and compilation of all existing hydraulic and morphological data in relation with the river system concerned have been made. The hydrometric data includes water level and discharge data. These data are necessary to define model boundary and to compare the model generated results with the observed data. It is worth mentioning here that within the Old Madhumati channel, there is no discharge or water level gauge station. Since the flow of this channel is governed by the flow in the MBR and the Madhumati River, available data for these two rivers have been collected. It is necessary to obtain more densely spaced bed level data in order to develop two-dimensional model. These data is needed to be collected during pre- or post-monsoon when the morphological activity is less than during the monsoon. To generate the computational grid for the two-dimensional model Bank line data were collected. Sediment data at Chapail ghat near the downstream end of the old Madhumati canal and the other at Haridashpur Bridge was also collected.

To analyse the sustainability of dredging, two dimensional morphological models have been developed by using MIKE 21C modelling tool. MIKE21C, two-dimensional modeling (hydrodynamic and morphological) is used as the main tool which simulates full hydrodynamic and morphological process of erosion of rivers with movable bed. MIKE21C applies curvilinear computational grid; it incorporates fully unsteady flow, bed load as well as suspended load including dynamic bed level changes through simple sediment continuity, updates the planform through bank erosion model and includes the computation of the secondary currents, and thus provides the 3D effects (IWM 2010).

5. ANALYSIS OF MORPHOLOGICAL CONDITIONS

With the help of available satellite imagery of the study area plan form characteristics of the Old Madhumati and MBR-Madhumati confluence have been analyzed (Figure 2). From the analysis, it is observed that the amount of siltation has increased in the Madhumati-MBR confluence. This is probably due to the reduced flow through the Gorai River. A char is observed in the downstream of the Madhumati-Old Madhumati confluence and the char is more pronounced in 2003 and 2005 than in 2001. This morphological change might be due to siltation in the Old Madhumati since this downstream char retards the flow through the Old Madhumati attracting more siltation. Reduction of the char periphery might be due to thrust of huge flow during 2004 in which flow was higher than that in 2003 and 2005. Width of the MBR is 185 m near the bridge and after meeting with the Madhumati at downstream, it increases. In the vicinity of the confluence of the Old Madhumati canal and the Madhumati, width is in the order of 600 m. Figure 3 shows the study area covering the MBR and the old Madhumati canal illustrating the bed levels at some of the important locations. It is seen from the figure that lowest bed level is at immediate downstream of the mouth of the old Madhumati canal and thalweg is located at opposite bank from the mouth. Lowest bed level is nearly -19.9 mPWD whereas near the mouth, it is around -9 mPWD. Analysis of the cross-sectional patterns in the vicinity of the bridge reveals the impact of the constriction scour and deposition of the scoured materials. Figure 4 shows the observed cross-sections taken near the bridge area. Cross-section at the bridge (line number J48) shows bed scour due to constriction made by the bridge. Going immediate downstream, sediment laden flow, getting un-constricted, is retarded and velocity is reduced. Due to reduction of flow velocity, these scoured materials are deposited on the bed which has been reflected on the downstream cross-sections, specially the cross section number J59, which is near the mouth of the old Madhumati canal.

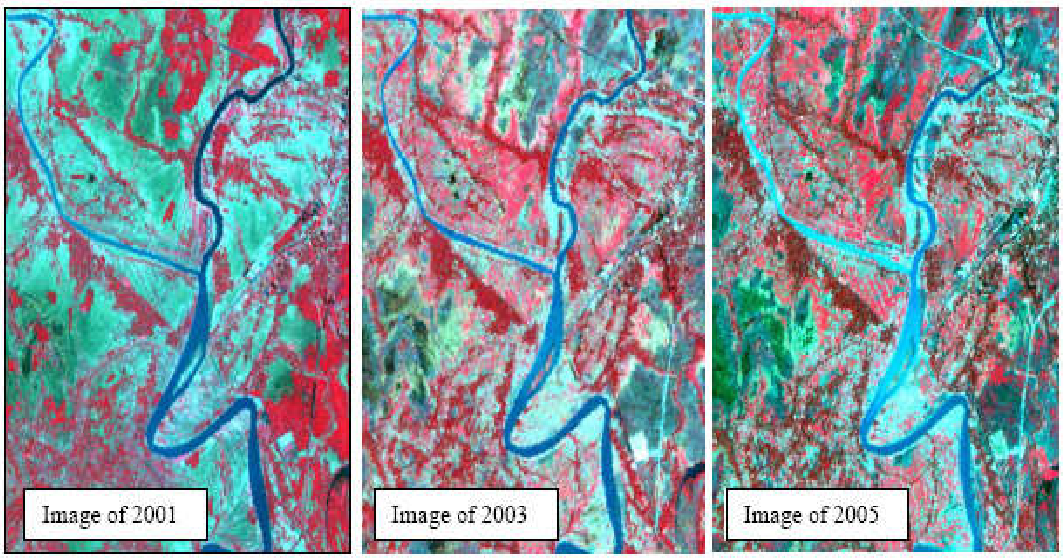

Figure 2 Satellite imageries of the study area indicating almost no change in shifting of bank lines of the MBR and Old Madhumati

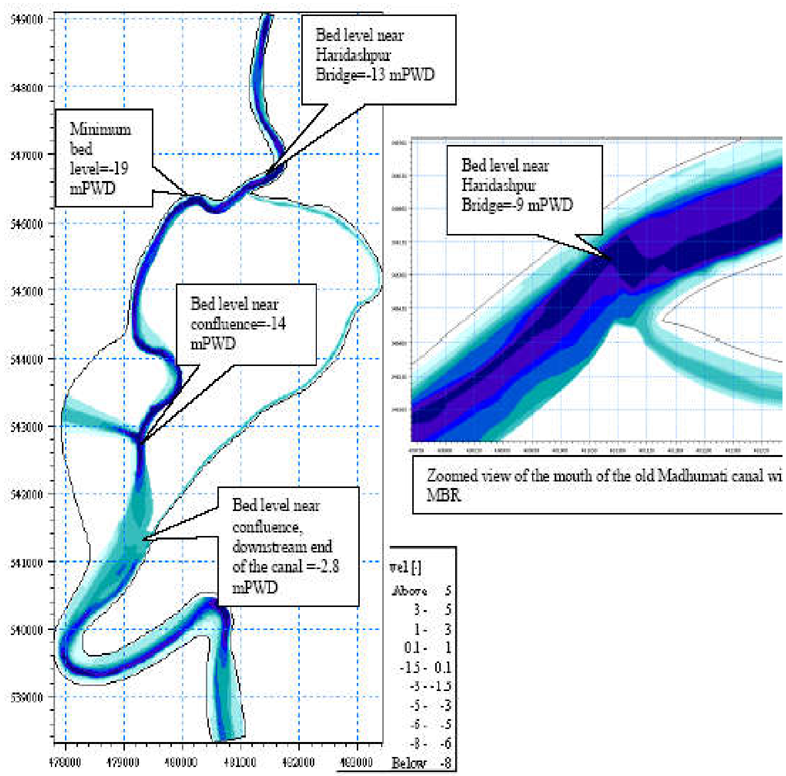

Figure 3 Study area of the MBR and Old Madhumati canal with description of bed levels

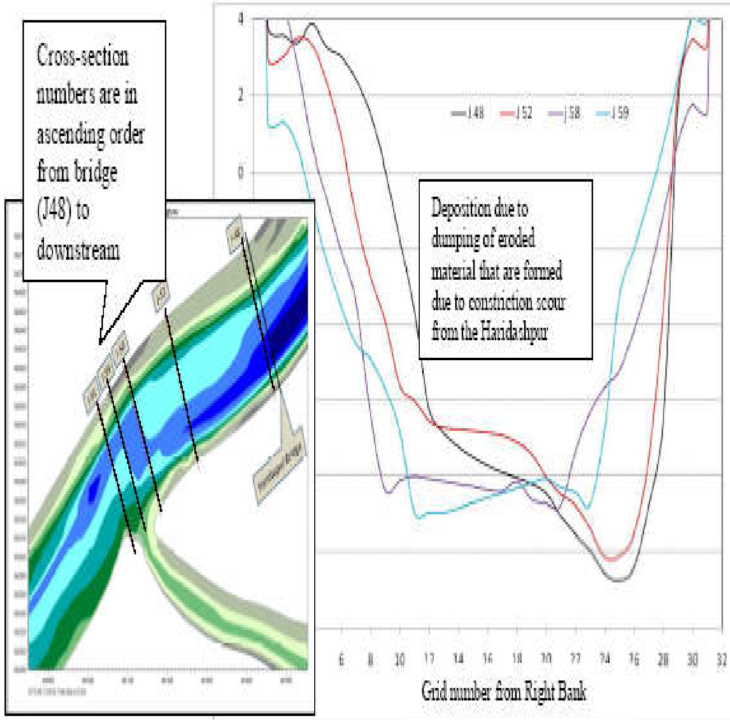

Figure 4 Cross-sectional changes in the vicinity of the Haridashpur Bridge

6. RESULT AND DISCUSSION

Two dimensional-model incorporating the design section of the old Madhumati canal as shown in Figure5 and hydraulic parameters as shown in Table 1 indicate that the amount of flow within the old Madhumati canal varies from 30 to 74 cumecs (Table 2) and model results for low flood event indicate that the flow within the canal would remain around 100 cumecs and water depth more than 1 m persists in the canal. Design velocity of the section varies from 0.5 m/sec to 1 m/sec as per model results for 1998 high flood event. Figure 6 show that the velocity within the canal is in the range of 0.25 m/sec to 0.75m/sec which does not exceed the maximum permissible velocity. However, near the mouth of the old Madhumati canal, more than 1 m/sec velocity has been found along the outer bend (Figure 7). Such high velocities might threaten the stability of the bank at this point. During peak of the high flood event 1998, other parts of the canal have been seen to experience water level from 4 to 4.5 m PWD and the water level at the mouth is 4.45 to 4.5mPWD (Figure8). As per the design of the section, highest water level of the canal at the bank is 4m PWD, which is higher if compared with the highest water level of 1991 but if compared with the water level of 1998, then it is lower. However, considering the dyke height, possibility of inundation is not likely. For low flood event of 1991, model results show that within the outer bend of the canal near the mouth, erosion takes place whereas at the other part of the same section and other parts of the canal, deposition is observed (Figure 9). On account of the inclination angle, i.e. curvature, such formation is observed. At this location, deposition varies between 0.2m to 1m. Middle part of the canal also indicates deposition slightly higher (1.5 m). Some deposition at other parts in the order of 1 m is also noticed. Deposition at the downstream end and at the mouth generates unfavorable situation which ultimately hinders the free flow through the canal. Tendency of bank erosion has been observed from model simulations at Old Madhumati offtake to nearly 500 m downstream. Investigating the hydraulic phenomena behind the deposition at the mouth and at the confluence point, three sensitivity tests (options) have been considered for improvement, i.e. for smooth passage of flow through the canal. These tests have been carried out following flood event of 1991. Option 1 has been prepared by shifting the existing starting location of the mouth of the canal with the MBR towards 200 m upstream (Figure10), option 2 considered lowering the existing bed level at the mouth from -1 mPWD to -5 mPWD (Figure11), and Option 3 dealt with two inclined groynes along the right bank of the MBR, opposite to the mouth of the canal (Figure 12). If comparison is made among the flow conditions and de-silting tendency within the canal for different options, then it is seen that lowering the bed level near the mouth of the canal poses favorable situation (Figure 13).

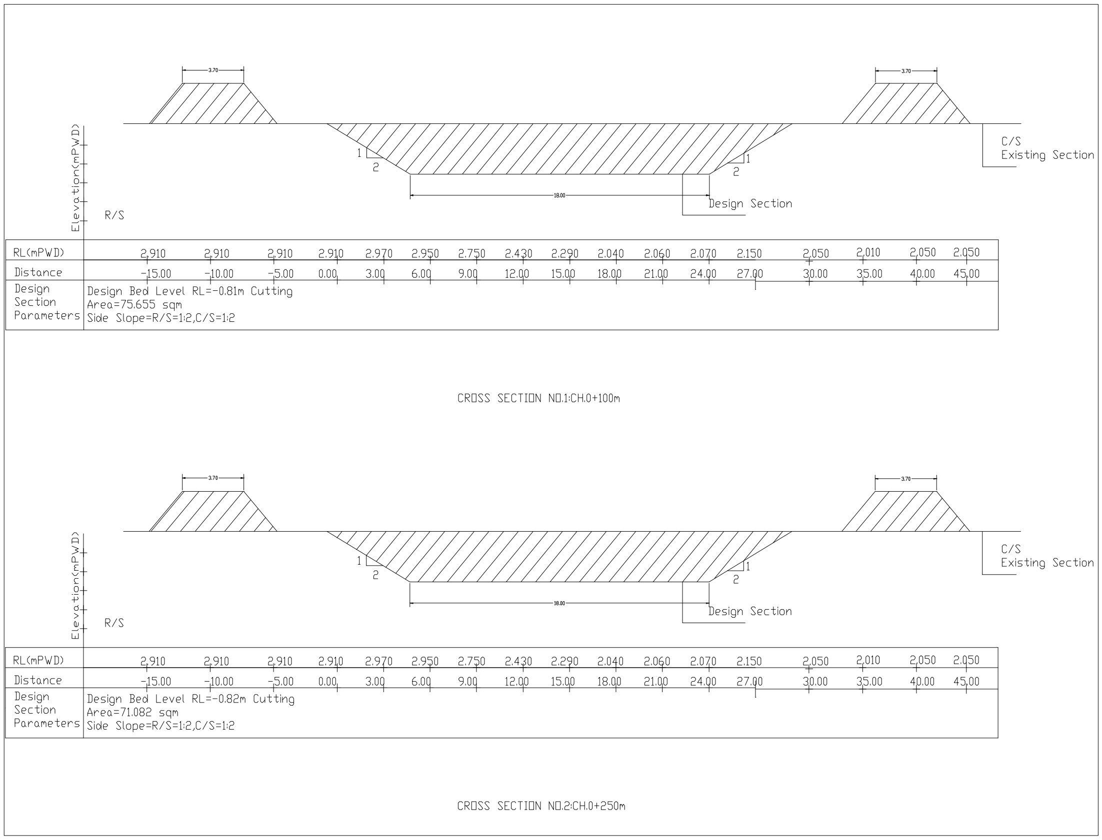

Figure 5 Dredging Cross section

Table 1 Existing hydraulic parameters of the Old-Madhumati canal

Chainage	Reach	Catchment Area (Ha)	Existing				
			Bed Level (mPWD)	BW (m)	TW (m)	Bank. GL (mPWD)	Bed Slope
Name of the Khal: Old Madhumati Khal, 1900 Km							
0	1	1900	2.67	18	25	2.69/2.76	-0.0003
1900			3.17	18	25	4.23/4.20	
Name of the Khal: Old Madhumati Khal, 1100 Km							
1900		1100	3.17	18	25	4.23/4.20	
3000			0.33	20	30	4.62/4.70	0.0026
Name of the Khal: Old Madhumati Khal, 2000 Km							
3000	2	2000	0.33	20	30	4.62/4.70	
5000			0.93	22	32	4.37/4.40	-0.0003
Name of the Khal: Old Madhumati Khal, 3320 Km							
5000	1	3320	0.93	22	32	4.37/4.40	
8320			0.56	25	35	3.48/3.50	0.0001

Table 2 Design hydraulic parameters of the Old-Madhumati canal

Design											
Drainage Rate (mm/day)	Q (m^3/s)	Basin WL (mPWD)	Outfall RWL (m)	WS	Side Slope	B (m)	d (m)	Chcek for V & Q	WL (mPWD)	BL (mPWD)	Depth of Cutting
Name of the Khal: Old Madhumati Khal, 1900											
	30000	3	2.31	0.0001	1.5	18	2.9	V=0.495	3	0.1	2.57
								Q=32.058	2.81	-0.09	3.26
Name of the Khal: Old Madhumati Khal, 1100											
	45000	3	2.31	0.0002	1.5	20	2.8	V=.894	2.81	-0.21	3.26
								Q=47.033	2.59	-0.81	
Name of the Khal: Old Madhumati Khal, 2000											
	55000	3			1.5	22	3	V=.729	2.59	-0.21	0.54
								Q=57.942	2.19	-0.81	1.74
Name of the Khal: Old Madhumati Khal, 3320											
	74000	3			1.5	25	3	V=0.889	2.19	-0.81	1.74
								V=8.701	1.227	-1.773	2.33

Morphology of the river system within the study area is governed by the combination of fresh water flow from upstream and tidal flow from downstream. Both the MBR and Madhumati rivers are associated with distinct meandering characters. Morphology of the MBR and old Madhumati canal has been assessed mainly with the analysis of the channel alignment and cross sectional changes. The hydrology of the study area is quite complicated because of the presence of tidal effect in the MBR and Madhumati River.

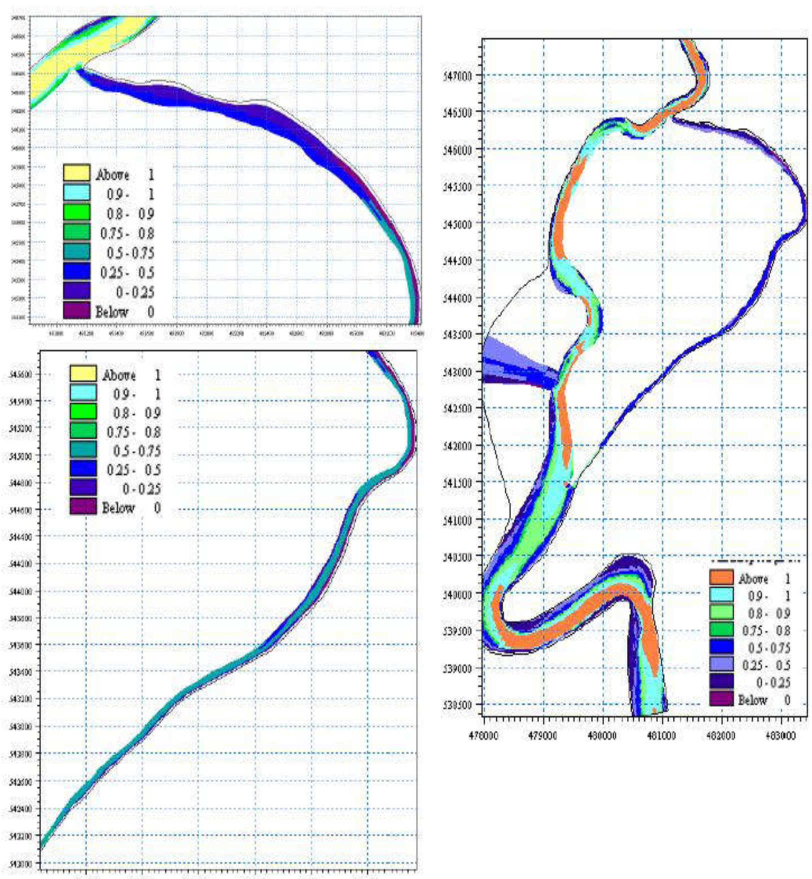

Figure 6 Simulated Peak velocities of the MBR-Madhumati river system and old Madhmati canal for extreme flood event of 1998.

On the basis of the model results for different scenarios and analysis of available data it is clear that annual dredging is required for maintaining the canal since siltation is observed from the model results, at the mouth as well as other parts of the canal that generates unfavorable condition for water to flow from the MBR into the old Madhumati canal. Starting location of the mouth of the canal is required to be shifted towards upstream as much as possible keeping smooth alignment with the MBR. Lowering of bed level should be done in order to avoid abrupt change at the distributary point, where bed level in the MBR is -6 mPWD whereas in the old Madhumati canal, it is in the order of -1 mPWD. This difference needs to be changed along with smoothening of bed level from MBR to the old Madhumati canal needs to be done. Construction of 500 m bank protection works (Revetment) is required from Old Madhumati off take to downstream at right bank to counter such possible bank erosion. Downstream end of the canal also needs to be monitored since the design for this part experiences higher velocity of flow. Generation of higher velocity may also cause bank de-stabilization.

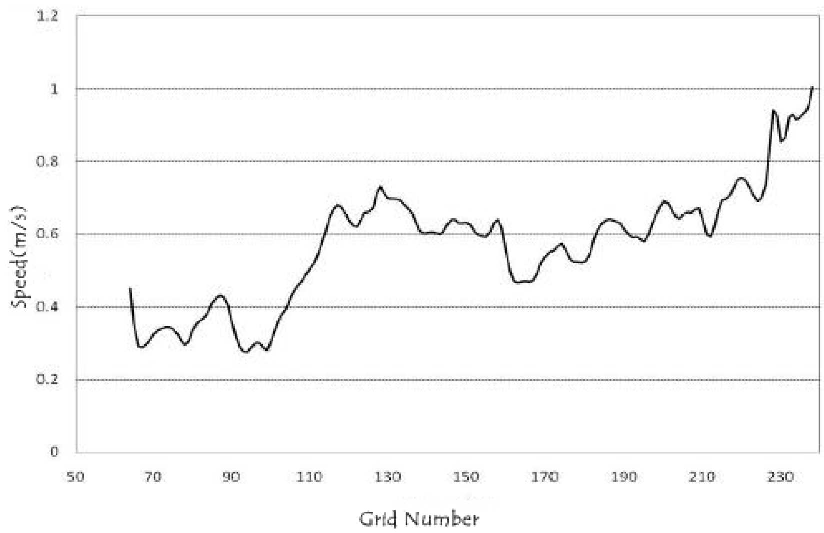

Figure 7 Simulated longitudinal velocity of the old canal during peak of 1998 flood event

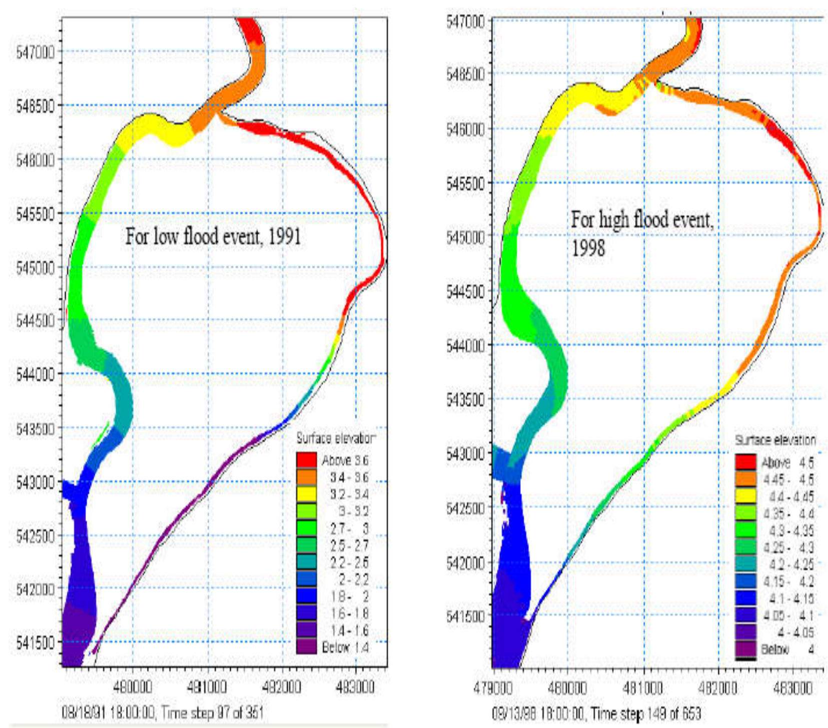

Figure 8 Simulated water levels for different events within the old canal

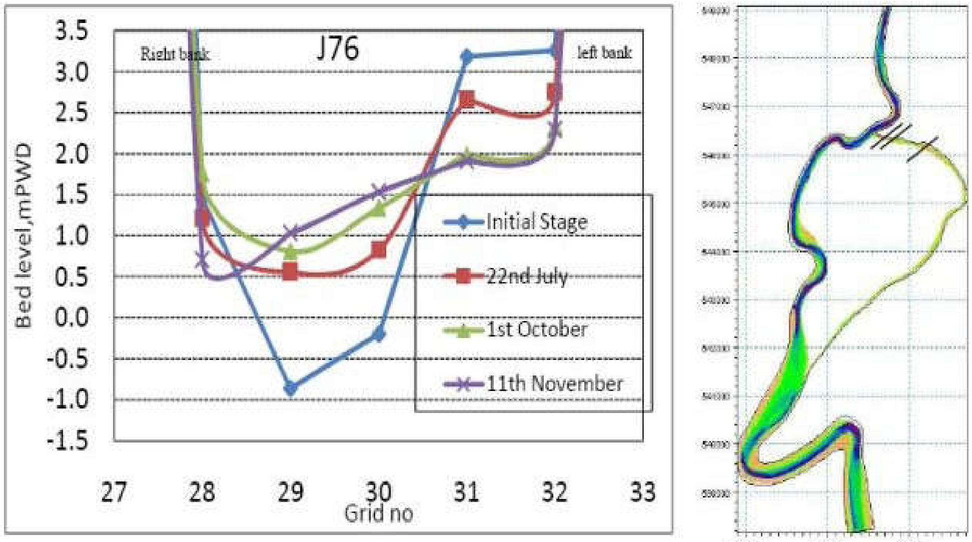

Figure 9 Cross sections at different stages of low flood event of 1991 indicating erosion at outer bend and deposition at mid part.

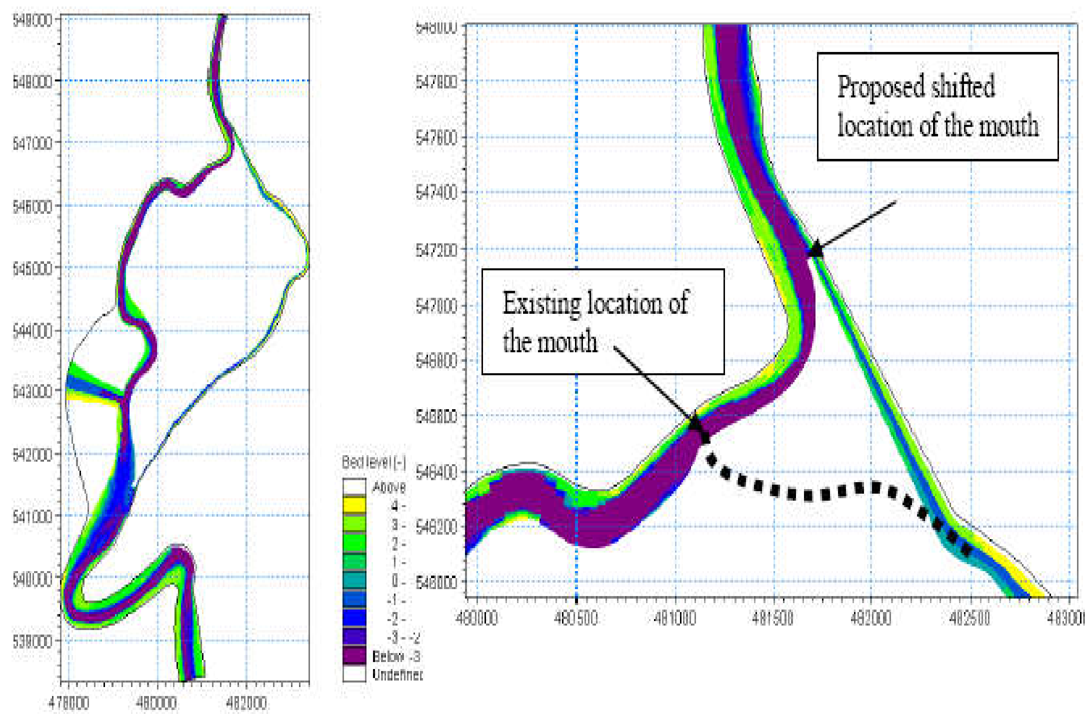

Figure 10 Proposed alignment of the canal at 200 m upstream from existing one

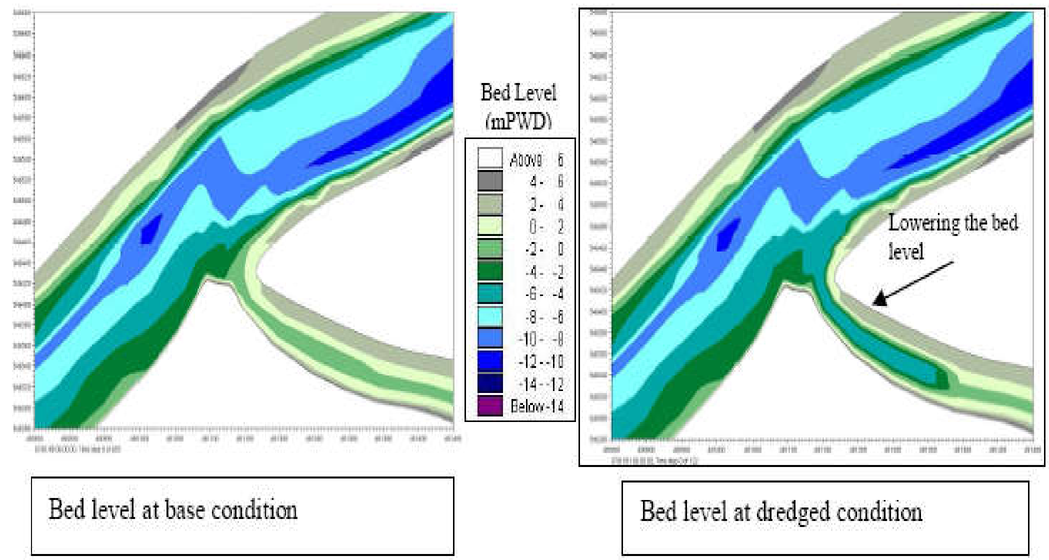

Figure 11 Bed Contour for two different set up;base condition (left) and dredged at mouth(right)

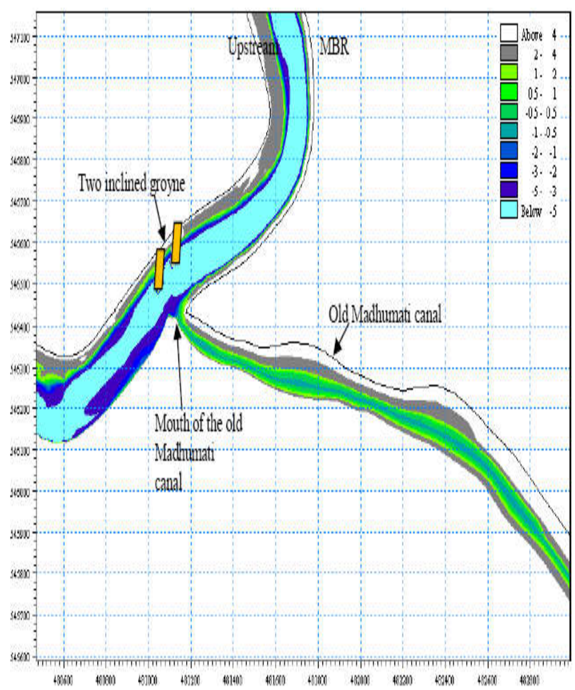

Figure12 Location of the proposed two groynes as incorporated in the model

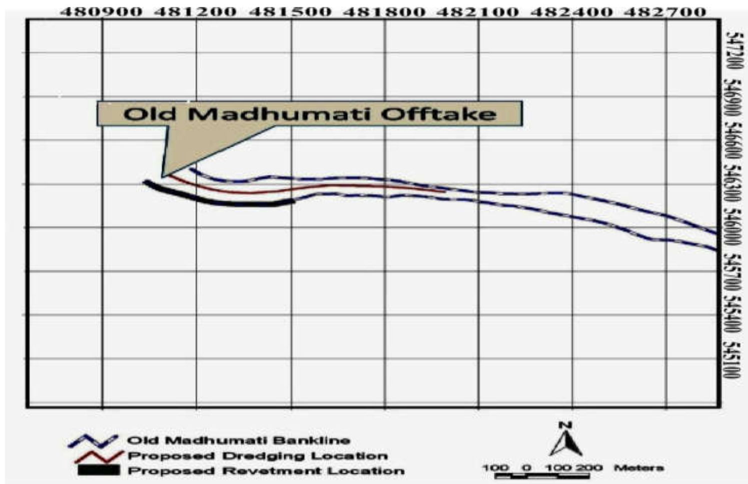

Figure 13 Proposed dredging and revetment locations on old Madhumati

According to the Environment Impact Assessment (EIA) the proposed intervention will bring some positive impacts such as improvement of flooding situation and drainage conditions. De-siltation of river bed is expected to remove water logging situation, salinity status, and improvement of surface water quality. Aquatic flora and fauna including fish, terrestrial flora and boat communication/navigation will develop. Agricultural production and irrigation for crop production will develop. Status of water pollution, communication, health hazard situation, aesthetic conditions and scope of recreation and scope of employment will improve. Some negative impacts like loss of land, displacement of some settlements/ people, enhancement of poverty for some displaced population, lack of awareness of the proposed development among the local people, creating worries and uncertainties among the local population affecting people's participation.

7. CONCLUSION

Required amount of flow within the old Madhumati canal varies from 30 to 74 cumec during lean season and model results for low flood event indicate that the flow within the canal would remain around 100 cumecs and water depth more than 1 m in the canal. Design velocity of the section is 0.5 m/sec to 1 m/sec and the model results for 1998 (high flood event) show that the velocity within the canal is in the range of 0.25 m/sec to 0.75 m/sec which does not exceed the maximum permissible velocity. However, near the mouth of the old Madhumati canal, more than 1 m/sec velocity has been found along the outer bend. Such high velocity might threaten the stability of the bank at this point. At this flood event, other parts of the canal have been seen to experience water level from 4 to 4.5 mPWD and the water level at the mouth is 4.45 to 4.5 mPWD. As per the design of the section, highest water level of the canal at the bank is 4 m PWD, which is higher if compared with the highest water level of 1991 but if compared with the water level of 1998, then it is lower. However, considering the dyke height, possibility of inundation is not likely to occur. For low flood event of 1991, model results show that within the outer bend of the canal near the mouth, erosion takes place whereas at the other part of the canal, deposition is observed. Presence of curvature influences the erosion and deposition which varies between 0.2m to 1 m. Middle part of the canal also indicates deposition slightly higher (1.5 m). Tendency of bank erosion has been observed from model simulations at Old Madhumati off take to nearly 500 m downstream. Environmental Impact Analysis shows that major improvement is expected to occur after implementation of the rehabilitation of the Old (Mora) Madhumati River.

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